

### **3.1.1 Geology**

The Moab site is at the northwest end of Moab-Spanish Valley along the axis of the Moab Valley salt-cored anticline ([Figure 3-1](#)). The northwest part of the valley is Moab Valley; the site is located at the mouth of Moab Canyon. The steep slope southwest of the site flanking Moab Valley rises 1,200 to 1,400 ft to the top of sandstone-capped Poison Spider Mesa. Just north of the site, north of US-191, and at the north end of Moab Valley is a steep slope rising approximately 600 ft that is composed of highly fractured and faulted sandstones.

#### ***3.1.1.1 Stratigraphy***

Rocks exposed and in subcrop in the area range in age from Middle Pennsylvanian to Middle Jurassic. These bedrock formations and their ranges of thickness are shown in [Figure 3-2](#). This section briefly describes the geologic formations in relation to the site. More detailed geologic descriptions are provided by Doelling et al. (2002) and are summarized in the SOWP (DOE 2003).

#### **Bedrock Formations**

The Paradox Formation was deposited in a periodically restricted part of the Paradox Basin. However, no outcrops of Paradox Formation are present in the immediate site area. No boreholes are known to have penetrated the Paradox Formation beneath the site.

The Honaker Trail Formation crops out as ledges on a steep slope west and south of the tailings pile. Up to 600 ft of Cutler Formation is exposed south and west of the site.

The Moenkopi Formation, also west of the tailings pile, consists of mostly red interbedded siltstone, fine-grained sandstone, and mudstone.

Outcrops of the Chinle Formation are located south of the tailings pile.

The Wingate Sandstone forms a prominent gray-pink to red-brown smooth cliff south and west of the tailings pile and forms a wall along the northeast side of Moab Valley and at the mouth of Courthouse Wash. The Wingate is faulted and highly fractured near the Moab anticlinal axis as it plunges southeastward into Moab Valley.

The Kayenta Formation caps Poison Spider Mesa to the south; north of the site, the formation crops out along the edge of Moab Valley near the mouth of Courthouse Wash.

Exposed at the site north of US-191, the Navajo Sandstone forms the northwest end of Moab Valley and dips moderately (about 50 degrees) southwest along the southwest flank of the Moab anticline.

One member of the Carmel Formation and one member of the Entrada Sandstone are present in the northwest end of the site area in the subsurface just north of the Moab Fault ([Figure 3-3](#)) in the lower end of Moab Canyon. The Dewey Bridge Member of the Carmel Formation overlies the Navajo Sandstone. The Slick Rock Member, which is the only member of the Entrada Sandstone in the vicinity of the site, is well-fractured in the subsurface along the Moab Fault zone.

### Quaternary Deposits

Except for the alluvial deposits, most Quaternary deposits are relatively thin. Because of the subsidence caused by removal of salt from the underlying Moab Valley salt-cored anticline, alluvium deposited mainly from the ancestral Colorado River has accumulated to a thickness of 450 to 500 ft beneath the site in Moab Valley. The subsiding Moab Valley has acted as a sump to catch Colorado River alluvium for much of Pleistocene time since erosion has begun “opening up” the Moab Valley salt-cored anticline and exposing the salt to dissolution by ground and surface waters.

The thick valley-fill alluvial deposits consist mainly of coarse gravelly sand, with minor silt and clay. Boulders as large as 1 to 2 ft in diameter, composed of resistant igneous and metamorphic rock types representing the upper Colorado River drainage, are common in the alluvium. At the mouth of Moab Canyon, the Colorado River alluvial deposits are mixed with and interlayered with generally fine-grained alluvium and detritus that has traveled down Moab Wash. Overlying the coarse alluvial deposits in the immediate site area in Moab Valley adjacent to the Colorado River is finer-grained alluvium of Holocene age composed mainly of sand, silt, clay, and minor lenses of gravel; this modern alluvium of the Colorado River covers much of the site area outside the tailings pile and is approximately 20 ft thick.

#### **3.1.1.2 Structure**

The Moab site is in the northern part of the ancestral Paradox Basin (see Figure 3–1). The salts deposited in this basin flowed toward northwest-striking faults in the basin floor, where they became thicker and formed northwest-striking elongate salt diapirs. Basins, called rim synclines, formed between the salt diapirs. Regional compression in Late Cretaceous to early Tertiary time formed broad northwest-striking anticlines and synclines, resulting in the Moab Valley salt-cored anticline (where the Moab site is located), the Courthouse syncline to the northeast of the site, and the Kings Bottom syncline to the southwest (see Figure 3–3). The northwest-striking Moab Fault (Figure 3–3) formed near the crest of the Moab Valley salt-cored anticline in mid-Tertiary time during a period of extensional faulting after regional compression.

Late Tertiary erosion allowed ground water to locally reach the upper parts of the salt diapirs through fractures and joints in the anticlinal folds. The resulting dissolution during late Tertiary and Quaternary time (and to the present) caused local areas of collapse, tilting, faulting, and subsidence of the overlying strata along the salt-cored anticlines. The degree of breaching (or opening up) of the salt-cored anticlines in this part of the Colorado Plateau largely reflects the amount of ground water that has been available for dissolution of the underlying salt and subsequent collapse. Ground water dissolves the salt and carries it away, leaving the insoluble part of the Paradox Formation as residue, called cap rock, on top of the leached salt diapirs.

#### **3.1.1.3 Geologic Resources**

In the site area, potash- and magnesium-bearing sylvite and carnallite are probably present in the salt wall, estimated to be at least 9,000 ft high and composed of the Paradox Formation in Moab Valley and adjacent Spanish Valley (Doelling et al. 2002). Similar deposits about 8 miles southeast of the site on the Cane Creek anticline (Figure 3–3) have been commercially extracted. Information is not sufficient to assess the extractability or value of the saline deposits.

Brine has also been produced from salt beds in the Paradox Formation about 2.5 miles southeast of the site. No oil or gas resources are known to exist beneath the site on the basis of oil and gas test holes drilled within 1 mile of the site.

The modern and older alluvium along the Colorado River, covering much of the site outside the tailings pile, contains sand and gravel suitable for highway and other construction. The considerable thickness of alluvial basin fill (up to 500 ft) beneath the site may also contain significant sand and gravel resources. A sand and gravel pit adjacent to the west edge of the site near the junction of US-191 and SR-279 was used by UDOT for highway construction and maintenance. This pit, UDOT 19076 (McDonald 1999) appears to be inactive.

Uranium and vanadium prospects occur south of SR-279 along the lower slopes of Poison Spider Mesa. No significant uranium-vanadium deposits are known to occur on the site; however, uranium and copper deposits have been identified in the lowermost part of the Chinle Formation about 8 miles northwest of the site.

#### ***3.1.1.4 Geologic Hazards***

Swelling clay (montmorillonite) is present in the Moenkopi and Chinle Formations along the west edge of the site. These bentonite-derived clays are capable of absorbing large amounts of water, accounting for the shrinking and swelling character of the formations and their derived soils.

Piping and rapid erosion may occur in fine-grained soils and unconsolidated fine-grained sediments at the site along the ephemeral stream channel of Moab Wash. The piping can occur when water from storms flows into permeable, noncohesive layers, removes fine sediments, and exits where the layer reaches the surface (Doelling et al. 2002). The void space created is a “pipe” that promotes accelerated erosion.

Active rock-fall areas are along the top of the slope of Poison Spider Mesa, which have the potential to reach the southwest border of the site.

Seismic and salt dissolution hazards associated with the Moab Fault were evaluated by Woodward-Clyde Federal Services (1996a). These hazards consist of the capability of the fault to rupture the surface of the site, the potential for salt dissolution and collapse at the site, and the potential of a microearthquake trend along the Colorado River.

In the vicinity of the site, the Moab Fault consists of two branches—the main Moab Fault and the west branch of the Moab Fault, which is exposed in places west and southwest of the site on the slopes of Poison Spider Mesa. The inferred trace of the main fault before salt dissolution passes through the site approximately across the northeast corner of the tailings pile (Doelling et al. 2002). No historical macroseismicity has been noted along the Moab Fault, and microseismicity studies have not revealed any earthquakes associated with the fault. The site area is in Uniform Building Code 1, indicating lowest potential for earthquake damage (Doelling et al. 2002). A concentration of seismicity was evaluated in a probabilistic seismic hazard analysis by Woodward-Clyde Federal Services (1996b). On the basis of that analysis, the recommended design-peak horizontal acceleration was 0.18g. For a 10,000-year return period for a strong earthquake, this value provides the level of protection equivalent to the extent practicable as specified in 10 CFR 100, “Reactor Site Criteria.” For these geologic and geophysical reasons, the

Moab Fault system is not a capable fault and does not pose a significant earthquake or surface-rupture threat to the present tailings pile.

Vertical subsidence rates in the northwest end of Moab Valley in the site area provide an estimate of the amount of collapse that could be expected from continued salt dissolution beneath the site. Rates of subsidence evaluated by Woodward-Clyde Federal Services (1996b) yield maximum estimates of 1 to 3 ft over 1,000 years. This deformation is expected to occur as a process of slow incremental displacements over time.

Radiocarbon dating of a wood fragment found deep in Colorado River alluvial deposits on the Moab millsite during monitor well drilling in summer 2002 provides another estimate of subsidence for the site. The carbonized wood fragment was in core from alluvial deposits at a depth of 116.5 ft in the boring for well MOA-435. The fragment was 89.5 ft below the top of gravel deposited by the Colorado River. A radiocarbon date of 45,340 years was determined for this wood fragment. Details of this wood occurrence and its radiocarbon dating are in the SOWP, Appendix D (DOE 2003). On the basis of this radiocarbon dating, a subsidence rate of approximately 2 ft per 1,000 years is indicated for the site; this rate is in the middle of the range (1 to 3 ft per 1,000 years) estimated by Woodward-Clyde Federal Services (1996b).

The rate of incision (downcutting) of the Colorado River where it has cut through sandstone bedrock upstream and downstream from the Moab site is much less than the estimated subsidence rate for the Moab Valley. The incision rate for this area has been estimated as 0.6 ft per 1,000 years by Willis (1992), using a dated volcanic ash bed preserved in a terrace at a known vertical elevation above the Colorado River. These subsidence and incision rates indicate that the tailings pile would become approximately 1.4 ft lower during the next 1,000 years in relation to the Colorado River.

### 3.1.2 Soils

Surface soils in disturbed areas of the site are predominantly sands mixed with clays, silts, and gravels and are saturated within 16 ft of the surface most of the year (NRC 1999). Remaining native soils surrounding the site are predominantly sands mixed with clays, silts, and gravels and are classified as Nakai fine sandy loams (Table 3-1). Soils include sandy loams to loamy fine sands. Soils are generally deep (depths greater than 36 inches), are well-drained, and have a minimal water-erosion potential, a moderate hazard of blowing potential, and an estimated erosion rate of 3 tons per acre per year. Additional information is available in the *Soil Survey of Grand County, Utah, Central Part* (SCS 1989).

**Subsidence** refers to the geologic process that is lowering the elevation of the entire tailings pile and the Earth's surface at the Moab site because ground water is dissolving the Paradox Formation salt deposits underlying the Moab-Spanish Valley. The rate of subsidence of the Moab-Spanish Valley is approximately 2 ft per 1,000 years. This gradual downward sinking of the tailings pile is partially offset by the gradual regional uplift of the Colorado Plateau.

**River incision** refers to the geologic process by which the Colorado River cuts down through the bedrock sandstone outcroppings located upstream and downstream of the Moab site. The rate of river incision in this area has been estimated as 0.6 ft per 1,000 years, much less than the estimated subsidence rate for the Moab Valley.

Over geologic time, the combined processes of subsidence and river incision will change the position of the tailings pile in relation to the underlying ground water and the Colorado River. As for ground water, these processes will eventually cause the bottom of the tailings pile to converge with the underlying ground water at an estimated rate of approximately 1.4 ft per 1,000 years. At this rate, DOE estimates that the tailings in the disposal cell would come into permanent contact with ground water in approximately 7,000 to 10,000 years, assuming the minimum depth to ground water ranges from 5 to 7 ft. As for the Colorado River, these processes will eventually lower the disposal cell by approximately 1.4 ft in relation to the river over the 1,000-year regulatory design period. This would place the 100-year floodplain of the river about 1.4 ft higher on the east toe of the cell, creating a higher probability for flooding over time. This potential impact would be very long term, and the potential hazard would be reduced by the proposed buried riprap diversion wall.